Tomorrow's Table

Organic Farming, Genetics, and the Future of Food

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The judicious incorporation of two important strands of agriculture—genetic engineering and organic farming—is key to helping feed the growing population in an ecologically balanced manner.

What kind of agriculture do we have?

CA Pesticide Use

- 180 million pounds pesticides used in 2004
- 1200 pesticide-related poisonings

Oregon Pesticide Use-2007

40 million pounds

- Long term health impacts--increased risk of prostate cancer, Parkinson's and other diseases

20% of Pesticides are used in Less Developed Countries

3 million cases of severe pesticide poisoning / year

300,000 deaths

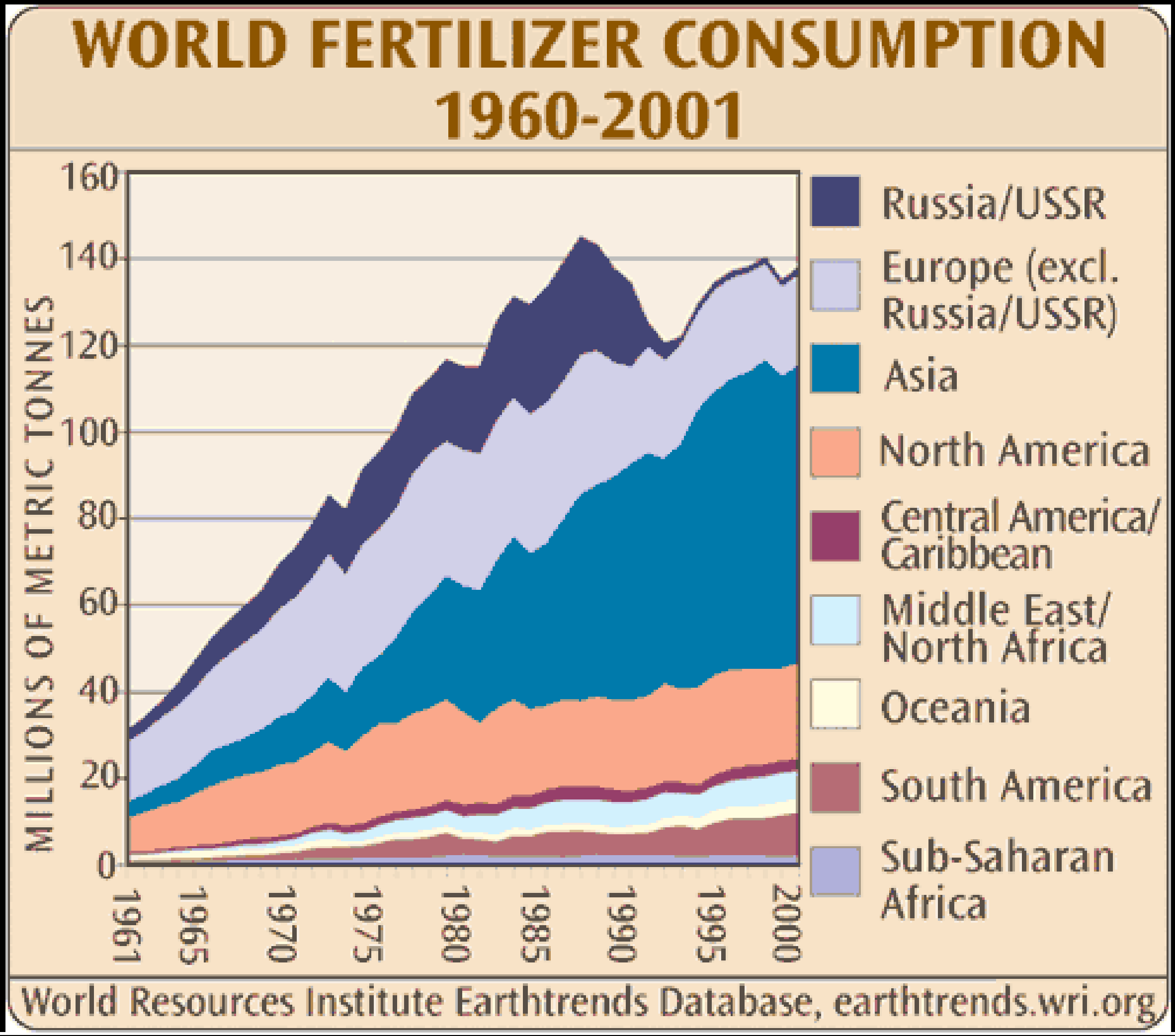
WHO, 2008

Slide courtesy of R. Nelson

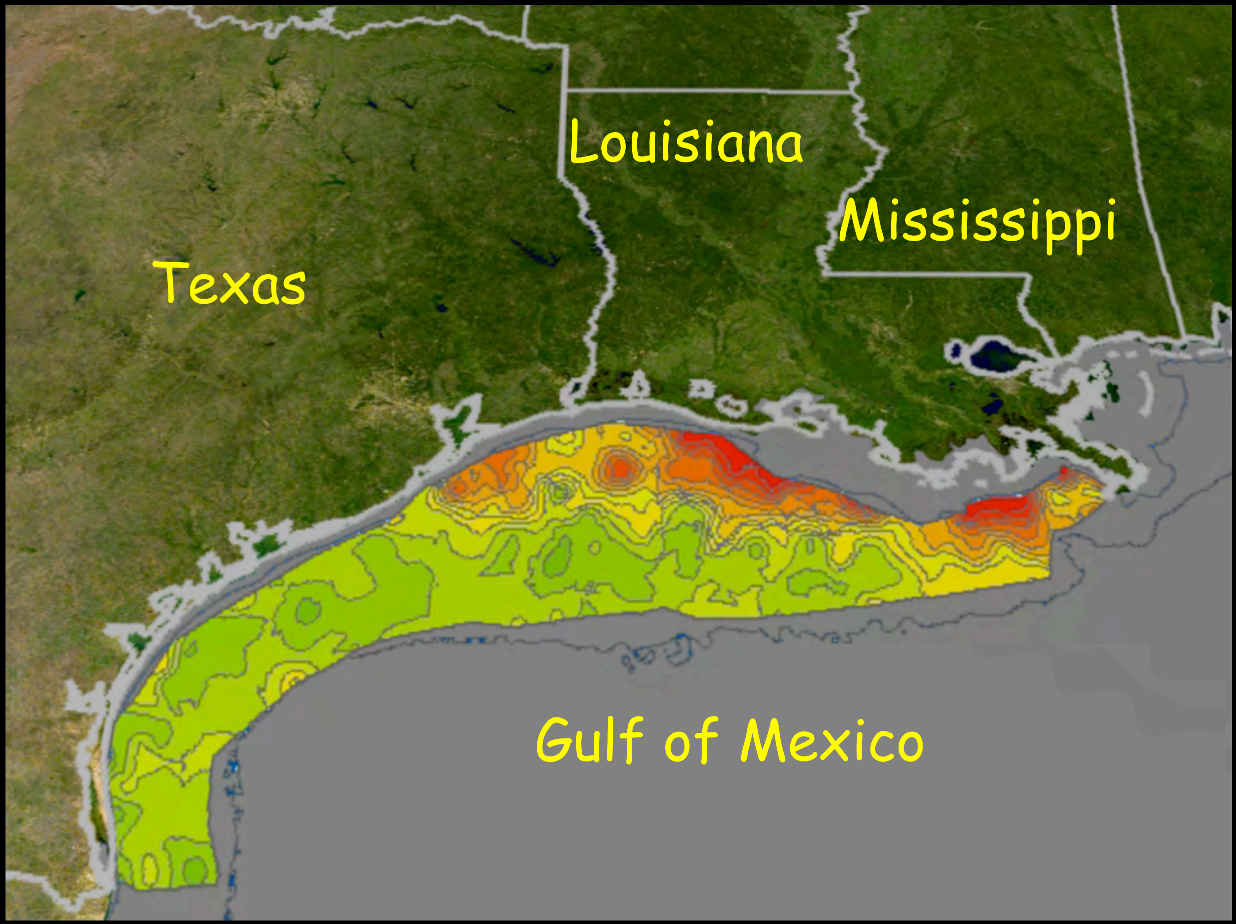
Conventional Agriculture depends on synthetic fertilizers

Synthetic nitrogen, phosphorus, and potassium fertilizers are soluble. They contaminate ground and surface water.

World Fertilizer Use

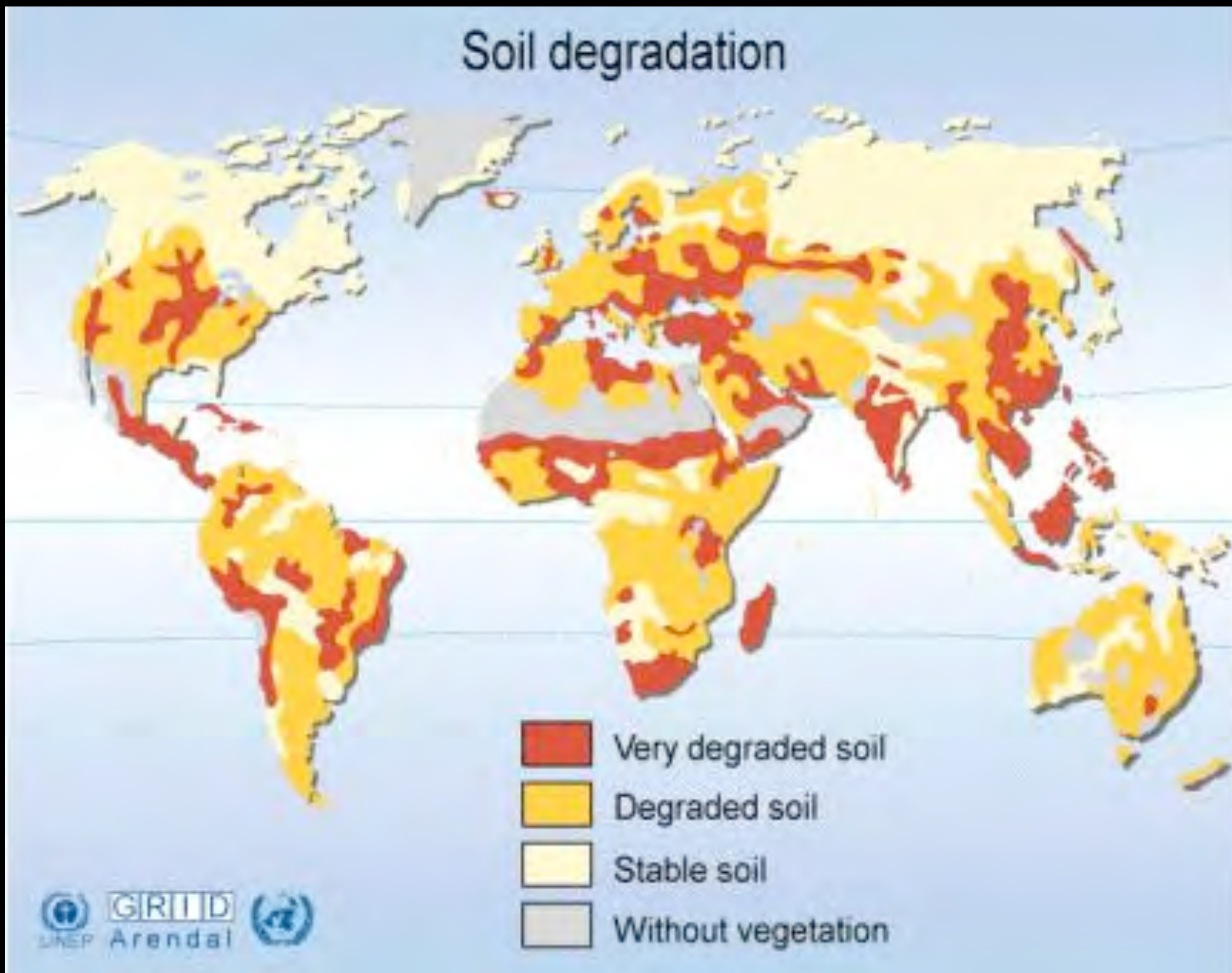


A 6500 sq mile dead zone forms each year at the mouth of the Mississippi River



Nasa satellite image

Agriculture causes soil erosion



30 percent of the world's arable land has become unproductive.

60 percent of eroded soil ends up in rivers, streams and lakes

United Nation
Environmental Program

If we continue with current farming practices we will have more of the same. More soil erosion, more fertilizer contamination of aquatic systems, more pesticide related injuries and loss of wild species.

There must be a better way to resolve the need for increased food production while minimizing its impact.

What criteria do we need to forge a Sustainable Agriculture?

- Provide abundant, safe and nutritious food
- Reduce harmful environmental inputs
- Reduce energy use
- Foster soil fertility and reduce soil erosion
- Enhance crop genetic diversity
- Maintain the economic viability of farmers and rural communities
- Protect biodiversity
- Improve the lives of the poor and malnourished

USDA

ORGANIC

UC Davis Student Farm
November 24, 2008

- Organic agriculture focuses on the health of crops, animals, farmers, environment, and consumers

Organic Agriculture uses 97% fewer pesticides than conventional systems

- Controls pests through crop rotation, support and enhancement of beneficial organisms, resistant varieties, and naturally occurring pesticides.

Fosters Soil Fertility

- Organic farming fosters soil fertility through use of compost.
- Less soluble and energy comes from sun

Cover crops build soil fertility

- Organic farming builds soil through use of cover crops (fix nitrogen in the soil) This reduces nutrient run-off and soil erosion.

Organic Ag for Developing Countries

- Organic agriculture requires fewer external inputs, including energy, and may be more suitable for locations where inputs are too costly or not available.

Is Organic Agriculture enough?

- Yields can be comparable to conventional farms depending on the crop and location, but for some key crops such as rice, yields are often lower.
- Some pests are difficult to control using organic methods
- Presently comprises only ca. 3% of all agriculture.
- Higher prices of organic food in developed countries may reduce availability to low income consumers.

›1 billion people are undernourished

33% of children ‹5 yrs in LDCs

Every day 24,000 die from malnutrition

By the year 2050 the number of people on Earth is expected to increase to 9.2 billion from the current 6.7 billion

Nairobi Feb, 2008

Without additional yield increases, maintaining current per capita food consumption will necessitate a near **doubling of** the world's **cropland area** by 2050.

- require deforestation
- reduce biodiversity
- strain water supplies
- cause soil erosion

Data Source: Green, R. et al. 2005. Farming and the fate of wild nature. Science 307:550-555.

photo ©Igor Dutina/iStock.com

Can modern genetic approaches such as genetic engineering contribute to sustainable agriculture?

Each GE crop needs to be evaluated to see that it meets criteria for sustainable agriculture.

- Depends on crop, location and farming practices

The corn that we eat today was created by the Native Americans some 8,000 years ago by domestication of a wild plant called **teosinte**

GE and precision breeding are modern approaches to seed modification that differs from conventional breeding :

- Only one to few genes introduced
- Genes from any species can be introduced (GE)

Both conventional and modern approaches result in a genetically modified crop that produces seed that can be saved by the farmer

GE and precision breeding can address problems that are difficult to tackle using conventional approaches

- Resistance to pests and diseases (insect, viral)
- Tolerance to environmental stress

Cotton uses approximately 25% of the world's insecticides

The Environmental Protection Agency considers seven of the top 15 pesticides used on cotton in 2000 in the United States as "possible," or "known" human carcinogens

- The bacterium Bacillus thuringiensis produces an insecticidal protein called Bt
- Used since the 1930s, Bt sprays are a favorite tools of organic farmers
- Bt gene cloned and introduced into crops.

Cotton bollworm

BT cotton kills 90% of cotton bollworms

After the adoption of BT cotton:

- In Arizona, growers cut their insecticide use in half while maintaining the same yield as their neighbors. Insect biodiversity increased.
- In China, insecticide use fell by 156 million pounds
- In India, yields increased 80 percent on small farm plots compared with neighboring plots growing conventional cotton *Science 2003* 299:900

But relying on a GE approach alone cannot solve the pest problem

After seven years of reduced insecticide use in China, populations of other insects increased so much that farmers resumed spraying certain kinds of pesticides

With organic farming practices these secondary insect populations could be held in check through crop diversity, the use of beneficial insects that feed on these pests and by rotating crops to reduce the overall pest populations


Papaya infected with papaya ringspot virus
• 1950s- Oahu crop destroyed by PRSV

Dennis Gonsalves engineers papaya for resistance

Gonsalves' group spliced a small snippet of DNA from a mild strain of the virus into the papaya genome.

Similar to human vaccinations against polio or small pox

This treatment immunized the papaya plant against further infection.

GE papaya yield 20x more fruit than non-GE

- 90% of all papaya was transgenic in 2003

- Occurrence of PRSV drastically decreased; benefits organic growers

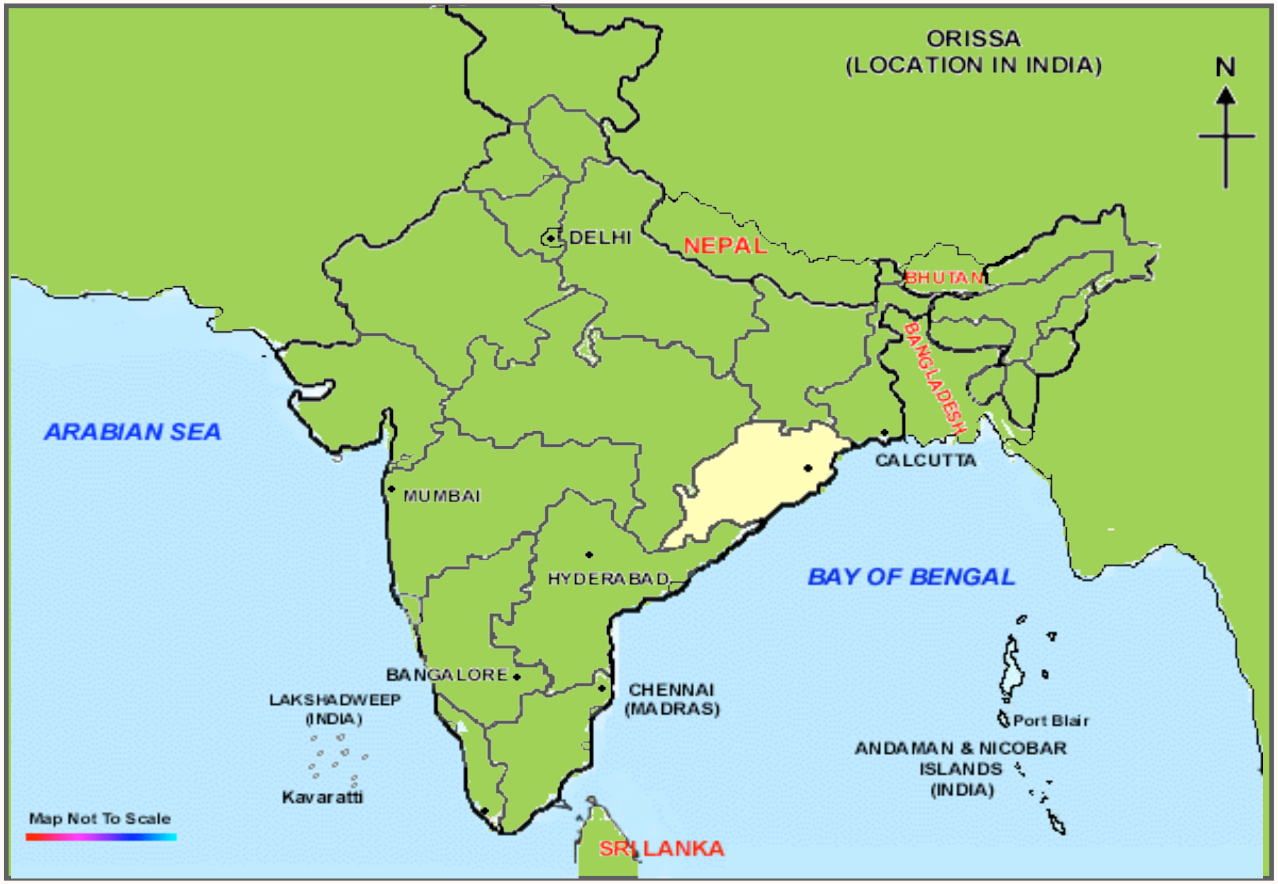
- Still not a sustainable system if not integrated with organic farming practices

25% of the world's rice is grown in flood-prone areas

75 million live on less than 1$/day

FR13A is a highly submergence tolerant rice line

FR13A is a submergence tolerant line collected in the 1940s from Orissa in eastern India



The rice line FR13A from India is Submergence Tolerant

- FR13A has poor grain and yield qualities but is unusual in its ability to endure complete submergence for ~ 14 days
- Attempts to breed tolerance into rice varieties favored by growers failed
- In 2006, my lab isolated the gene called Sub1 that confers tolerance to flooding and engineered a tolerant rice
- Precision breeding carried out with multiple varieties (Mackill, IRRI)

IR64-Sub1 rice June-Oct 2007
The International Rice Research Institute

IR64-Sub1 vs IR64
2007 Yield Comparisons

3.8 t/ha 1.4 t/ha

Sub1A is sufficient to confer tolerance to nearly all intolerant varieties (5-6 fold yield increase)

New *Sub1* lines after 17 days submergence in IRRI field

Xu et al., Nature 2006; Slide Courtesy of D. Mackill

In flooded fields in Bangladesh, Sub1 rice yielded 2-3 fold more grain than conventional varieties

Dr. Md Abdul Mazid Bangladesh Rice Research Institute, Rangpur

http://pamelaronald.blogspot.com/

“I was surprised and happy when I saw that the Sub1 rice survived the flood”

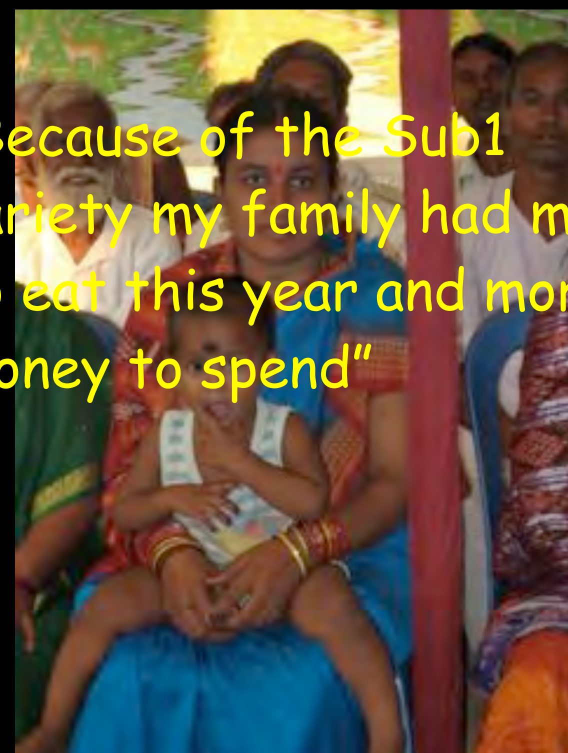
Harir Danga farmer, Bangladesh

Video courtesy of Gene Hettel IRRI

Soccer celebration in Harir Danga rice fields, Bangladesh

Video courtesy of Gene Hettel IRRI

In flooded fields in India, villagers were able to harvest more rice for their families



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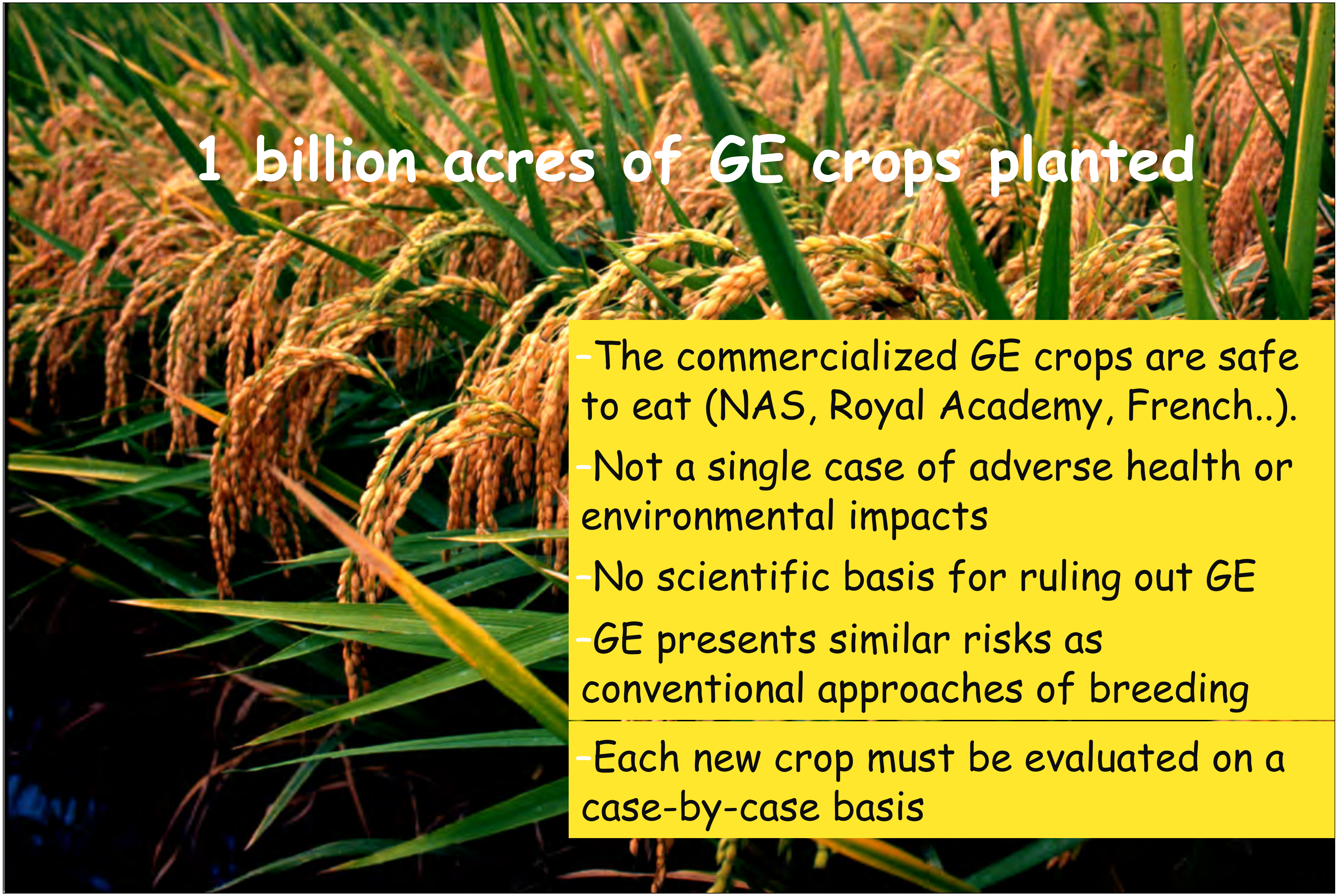
Are genetically engineered crops safe to eat?

1 billion acres of GE crops planted



- The commercialized GE crops are safe to eat (NAS, Royal Academy, French..).
- Not a single case of adverse health or environmental impacts
- No scientific basis for ruling out GE
- GE presents similar risks as conventional approaches of breeding
- Each new crop must be evaluated on a case-by-case basis

The Future of Food

- Farms of the future must produce enough affordable food to feed all the people in a manner that greatly reduces toxic inputs, minimizes nutrient run-off and soil erosion.
- Organic production systems and GE crops can make a major contribution to reaching these goals, just as plant breeding was of crucial importance to increased food production in the 20th century.

“A truly extraordinary variety of alternatives to the chemical control of insects is available. Some are already in use and have achieved brilliant success. Others are in the stage of laboratory testing. Still others are little more than ideas in the minds of imaginative scientists, waiting for the opportunity to put them to the test. All have this in common: they are biological solutions, based on understanding of the living organisms they seek to control, and of the whole fabric of life to which these organisms belong. Specialists representing various areas of the vast field of biology are contributing—entomologists, pathologists, geneticists, physiologists, biochemists, ecologists—all pouring their knowledge and their creative inspirations into the formation of a new science of biotic controls."

Rachel Carson, 1962